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FTR Fuel Burnup: A REBUS-2, 2DB Comparison Study

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## COLUMN TO TRAIL

FTR Fuel Burnup: A REBUS-2, 2DB Comparison Study

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#### ABSTRACT

Using a typical FTR fuel cycle burn step problem, a comparison is made of the quantities predicted by the Westinghouse 2DB and ANL REBUS-2 fuel management codes. The quantities considered for comparison are power fractions and shifts, burnup, and EØC fuel inventory. These data are given for 14 sample regions. Excellent agreement was observed for all quantities, particularly the EØC atom densities.

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## I. INTRODUCTION

As a result of an RRD-sponsored Fuel Management Code Meeting held at Argonne National Laboratory (October 5-6, 1972), a commitment was made to execute a reference FTR fuel management problem selected by WARD, using both the ANL REBUS-2 and WARD 2DB codes. The primary purpose of this exercise was to provide an intercomparison of the WARD and ANL computational capabilities and to check the suitability of the REBUS-2 code for use in an FTR calculation.

The specific problem selected by WARD was the fuel burnup for the fourth cycle which is a typical FTR equilibrium cycle. Additionally, it was decided the problem comparison should be done using the same FTR 21 group cross section set utilized by WARD. The 21-group cross section set used by WARD in these calculations was transmitted to ANL in October 1973. Since these cross section data were supplied on punched cards in a unique format they were first converted to the CCCC (Committee on Computer Code Coordination) format of ISØTXS which was subsequently translated to the ARC System XS.ISØ format.

The following section describes the details of the cycle 4 burnup problem as determined by an examination of the 2DB computer output supplied by WARD. The specific numerical results obtained are presented in Section III and discussed in Section IV.

## II. PROBLEM DEFINITION

The basic problem to be executed for comparison is a 94.262-day irradiation of an FTR two-dimensional hexagonal mesh core mockup using the 21-neutron energy group FTR cross section set provided by WARD. The core layout is shown in Fig. 1 which indicates the principal components and areas. Specifically, these are the inner and outer core areas, the four closed loops, the inner and outer control, the two material test regions, the peripheral control, the ring 7 reflector, and the ring 8 and 9 reflector. The remaining hexes of ring 9, not drawn in the map, are filled with sodium. These 241 hexes have been assigned to 109 different

As a result of an MRD-sponsored for) Management Code Marting held at Argoine National Laboratory (Dotober 5-6, 1972), a commitment was made to execute a reference FTR foot management problem selected by MARD, using both the AML REBUS-2 and WARD 208 codes: The primary purpose of this exercise was to provide an interconcarigon of the WARD and AML computational capabilities and to check the suffability of the REBUS-2 code for use in an FTR calculation.

The specific problem selected by VARD was the fuel burnup for the fourth cycle which is a typical FIR equilibrium cycle. Additionally, it was decided the problem comparison should be done using the same FIR 21 group cross section set utilized by VARD. The 21-group cross section set used by WARD in these calculations was transmitted to AML in October 1973. Since these cross section data were supplied on punched cards in a unique format they were first converted to the CCCC (Committee on Computer Code Code Instituted to ISBIXS which was subsequently translated to the AMC System XS.153 format.

The following section describes the details of the cycle 4 burnup problem as determined by an examination of the 208 computer output supplied by MARD. The specific numerical results obtained are presented in Section III and discussed in Section IV.

# fi. PROBLEM DEFINITION

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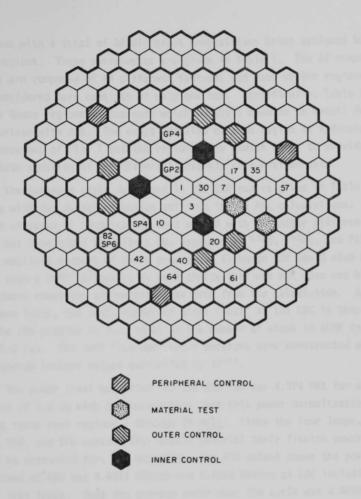


Fig. 1. Core map for reference FTR fuel management problem.



ing. I Corn map for reference Tik fur! denoughers problem.

regions with a total of 87 different compositions being assigned to the 109 regions. These assignments are given in Table I. The 87 compositions are composed of 44 different isotopes and each of the regions to be considered here consists of only one hex. Specifically, Table II lists those regions of the core which we shall examine in detail for comparison with 2DB. The exact location of each region is indicated on the core map of Fig. 1 and the regions were chosen so as to provide a complete sampling of the different possible core environments.

The isotopic chain data used in the 2DB run is given in Table III along with two different chains utilized in the ANL calculations. The first of these is identical to that of 2DB with the minor difference that DUMP has been added to collect the captures by  $^{235}$ U,  $^{242}$ Pu, and FISHP and take explicit account of their presence. Although 2DB could also have used such a DUMP collector, by user choice this was not done and hence the above reactions are permitted to drop from the calculation. As will be seen later, the small number of atoms "lost" at the EØC in this manner in the 2DB problem is just equal to the number of atoms in DUMP in the REBUS-2 run. The DUMP "isotope" cross sections were constructed using the sodium isotope values multiplied by  $10^{-10}$ .

The power level specified for the 2DB run was 4.374 MWt for a core height of 1.0 cm with the restriction that this power normalization is to be taken over regions 1 through 76 only. Since the four loops, GP2, GP4, SP4, and SP6 contain fissionable material their fission power must also be accounted for. In actuality, the 2DB output shows the power attained at BØC was 4.4091 MWt/cm and 4.4083 MWt/cm at EØC including the four test loops. Thus the average power over the cycle was 4.4087 MWt/cm. This is the power level used in the ANL calculation.

As an integral feature of the 2DB code, the 94.262-day burn period is divided into 10 equal subintervals. Using the original flux computed for BØC the code simply renormalizes this flux to the desired power at the end of each subinterval. The REBUS-2 calculation was performed in a like manner. A BØC explicit neutronics solution yielded the initial fluxes for t = 0. These fluxes were then renormalized at each subsequent subinterval to achieve the desired power of  $4.4087 \, \text{MWt/cm}$  except that at EØC (t =

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KEBUS-2 run. The DRMM "lastope" cross sections were constructed at 180.

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As an internal resture of the 200 code, the 04 205 day burn period in divided into 10 equal-subintervols. Using the condutal filts computed for EDC the code simply reconsilise this limit to the desired power at the ends subinterval. The MERUS-1 calculation was performed in a pitch manner. A EDC explicit neutronics solution yielded the initial filuxes for t. C. These fluxes were then renormalized at each subsequent subinterval to active encopy that at EDC (t. )

TABLE I. Composition Assignments for FTR Test Problem

Composition Number	on	Region Assignment	Description
44 to 73		1 to 30	inner core fuel
74 to 119		31 to 76	outer core fuel
120 121 122 123		79 80 81 82	"fuel" for loop GP2 "fuel" for loop GP4 "fuel" for loop SP4 "fuel" for loop SP6
124		83, 84, 85	inner control channel
127		86 to 91	outer control rods
128		77, 78	material test loops
129		92 to 95 97 to 99 102 to 105 107	reflector, ring 7
130		108, 109	reflector, ring 8 and portion of ring 9
131		100	Na background, remainder of ring 9
132		96, 106, 101	peripheral control

ADLE P. Composition Assignments for FTR Test Problem

TABLE II. FTR Regions Used for Comparison

Region Number	= HEX Number*	Location
1	PART 1 FISHE	central hex, ring l
3	3	inner core, ring 2; next to inner control rod
30	30	inner core, ring 2
7	7	inner core, ring 3; next to material test loop
10	10	inner core, ring 3; next to loop SP4
17	17	inner core, ring 3
20	20	inner core, ring 4, between two control rods
35	35	outer core, ring 5
40	40	outer core, ring 5; next to control rod
42	42	outer core, ring 5
57	57	outer core, ring 6
61	61	outer core, ring 6, corner
64	64	outer core, ring 6; next to peripheral control
82	82	loop SP6, ring 6

<sup>\*</sup>See Fig. 1.

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See Fig. 1.

TABLE III. Isotope Chains Used

## 2DB Chain:

(n,f) reactions	(n,γ) reactions
$^{235}$ U $\rightarrow$ FISHP $^{238}$ U $\rightarrow$ FISHP $^{239}$ Pu $\rightarrow$ FISHP $^{240}$ Pu $\rightarrow$ FISHP $^{241}$ Pu $\rightarrow$ FISHP $^{242}$ Pu $\rightarrow$ FISHP	$\begin{array}{c} 238\text{U} \rightarrow 239\text{Pu} \\ 239\text{Pu} \rightarrow 240\text{Pu} \\ 240\text{Pu} \rightarrow 241\text{Pu} \\ 241\text{Pu} \rightarrow 242\text{Pu} \end{array}$

## REBUS-2 Chain:

Same as 2DB chain above plus,

# (n,γ) reactions FISHP $\rightarrow$ DUMP <sup>235</sup>U $\rightarrow$ DUMP <sup>242</sup>Pu $\rightarrow$ DUMP

## REBUS-2 Extended Chain:

(n,f) reactions  235U 238U 239Pu 240Pu 241Pu 242Pu  135Xe 149Sm → P9FP1 P9FP2 P9FP2 P9FP3	Yield fraction 0.0715 0.0130 0.0134 0.4010 1.5011 2.0000	(n,γ) reactions 238U → 239Pu 239Pu → 240Pu 240Pu → 241Pu 241Pu → 242Pu 135Xe → DUMP 149Sm → DUMP P9FP1 → DUMP P9FP2 → DUMP P9FP3 → DUMP 235U → DUMP 242Pu → DUMP
(n,2n) reactions  242Pu → 241Pu 241Pu → 240Pu 240Pu → 239Pu	(n,α) re <sup>149</sup> Sm =	
$239$ Pu $\rightarrow$ DUMP $235$ U $\rightarrow$ DUMP $238$ U $\rightarrow$ DUMP	<u>(n,p) re</u> 239Pu →	

# TABLE 111. Isotope Chalus para

94.262 days) another explicit neutronics solution was performed rather than renormalization. However two different methods were used in performing the burnup from subinterval to subinterval. If we denote the end point of the k-th subinterval as time point t = k then there are a total of 11 time points at which the atom density are computed, namely, BØC or t = 0, t = 1 through t = 9, the endpoints of subinterval 1 through 9, and finally EØC or t = 10. Letting  $A_{M,R}^k$  be the burn matrix for material M in region R then the equation governing the change in atom densities is

$$\frac{d}{dt} \vec{N}_{M,R}(t) = A_{M,R}^{k} [\phi_{R}(t)] \vec{N}_{M,R}(t) , \qquad t_{k-1} \leq t \leq t_{k} , \qquad (1)$$

where  $\vec{N}_{M,R}$  is the atom density vector for material M in region R and  $\phi_R(t)$  is the flux in region R at time t. Defining the transmutation matrix  $B_{M,R}^k$  as

$$B_{M,R}^{k} = \exp\left[A_{M,R}^{k} * T\right], \qquad (2)$$

where T is the length of a subinterval, i.e., 94.262 days/10, the atom densities at t =  $t_k$  are then found from those at t =  $t_{k-1}$  by the expression

$$\overrightarrow{N}_{M,R}(t_k) = B_{M,R}^k * \overrightarrow{N}_{M,R}(t_{k-1}) .$$
(3)

Two forms of the burn matrix are considered in the solution of Eq. (1), namely

$$A_{M,R}^{k} \left[ \overline{\phi}_{R}(t) \right] = A_{M,R}^{k-1} \left[ \overline{\phi}_{R}(t_{k-1}) \right]$$
(4)

or

$$= \frac{1}{2} \left\{ A_{M,R}^{k} \left[ \phi_{R} \left( t_{k} \right) \right] + A_{M,R}^{k-1} \left[ \phi_{R} \left( t_{k-1} \right) \right] \right\}. \tag{5}$$

94.262 days) another explicit neutronics solution has performed rether than renormalization. However has alliferent methods were used to performing the barrup from subinterval to subinterval. If we despite the end point of the k-it subinterval as time point the end of IT time worsts as which the area density are supported, namely.

9, and finally the or t = 10, testing A<sub>1,0</sub> as the burn matrix for mother with the ending the end of the subinterval at the substant of the substant

purers & to the atom consists vactor for meterial M in region B and of (2) is the frankmination as time t. Defining the frankmination matrix B. as

where T is the length of a subinterval, i.e., 94.262 dais/10. the expression densities at t = t, are then found from those at t = t, by the expression

Two forms of the burn matrix are considered in the solution of Eq. (1).

$$\left[\left(z_{-2}^{2}\right)_{R}^{2}\right]_{R,R}^{1-2} = \left[\left(z\right)_{R}^{2}\right]_{R,R}^{2}$$

70

Equation (4) represents the solution method used in the 2DB code, namely, the burn matrix at time point t=k-1 is used in performing the burnup to achieve the atom densities at the next time point, t=k. Equation (5), on the other hand, is the normal method of operation for the REBUS-2 code. The burn matrix for time point k-1 is first used to predict the atom densities at t=k. These atom densities are then used to determine the fluxes at t=k, in this case a simple renormalization to the specified power, which are then used in constructing a burn matrix for the k time point. The arithmetic average of the k-1 and k burn matrix is then used in Eq. (3) to obtain a revised set of atom densities at time point k.

The results for both methods of solution are presented here and compared with the 2DB values. To distinguish between them, the second method in which Eq. (5) is used will be referred to as the "average A matrix" method.

## III. COMPARISON

# Computational Results

5

The amount of poison in each of the six outer control rods in the 2DB run was such as to give a BØC  $k_{\rm eff}$  of 1.011805. Hence the poison of the REBUS-2 runs was adjusted to give the same BØC  $k_{\scriptsize eff}$  value before the burn was even attempted. The results of the two runs, one with and one without A matrix averaging are shown in Table IV along with the 2DB values. As might be expected the REBUS-2 run without burn matrix averaging most closely duplicates the 2DB figures. The principal difference between the two codes is the amount of poison required to achieve a BØC  $k_{\rm eff}$  of 1.0118. The REBUS-2 code requires 2% less poison. If the 2DB poison eigenvalue is used in the REBUS-2 calculations, a BØC  $k_{\rm eff}$  of 1.011412 is obtained, which differs from the 2DB value by 0.04%. The small eigenvalue difference (approximately 12 cents) using the same BØC atom densities and cross sections provides an excellent cross check of the neutronics of both REBUS-2 and 2DB. The data of Table IV indicate a slope of  $\Delta k_{eff}/\Delta x$  x=0.285 = -0.070 for the REBUS-2 run with no averaging of the A matrix. The 2DB output data, on the other hand, yields a figure of  $\Delta k_{eff}/\Delta x = -0.091$ .

Equation (4) remissions the solution manned ease to the 200 total number, the burn relates at the solution in the controlling the burnup the burnup the burnup the school is on the other number, is the name, is the name, is the name, is the school of operation for the standard burn eaters for the scient k. I be the treat used to predet the standard densities at t. k. These atom densities are the used to desemble the power, which are then used to constructing a burn eaters for the specified power, which are then used to constructing a burn eaters for the their power, which are then used to constructing a burn eaters for the their time points in the time points in the filling points. It

The Fewells for both methods of solution are presented here and compared with the TD values. In distinguish between them, the secured method in which Eq. (5) is used will be referred to as the "dwerker A matrix" method.

III. COMPARISON

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TABLE IV. FTR Comparison, Reproduction Constant

	2DB	REBUS-2	Δ, %a	REBUS-2, averaged A matrix	Δ, % <b>a</b>
BØC k <sub>eff</sub>	1.011805	1.011806	0.0000	1.011806	0.0000
EØC keff	0.984075	0.984053	-0.0022	0.984000	-0.0076
∆keff	0.027730	0.027763	0.0829	0.027806	0.2741
Δρ	.027850	0.027874	0.0862	0.027928	0.2801
Control Eigenvalue	0.28491	0.27930	-1.9690	0.27930	-1.9690
ВОС р	0.0116672	.0116682	0.0086	o.0116682	0.0086
EØC p	-0.0161827	0162054	0.1403	-0.0162601	0.4783

aRelative to 2DB.

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Table V lists the burnup computed for each of the 14 comparison zones. Though the REBUS-2 figures agree to within several percent of the 2DB values, the averages show that the REBUS-2 values are uniformly high. Since the comparison figures are in terms of MWD/MT the computed values depend on the values used for the atomic weights as well as the value of Avogadro's number. For the REBUS-2 calculations it was assumed the 2DB code used a value of  $0.60225 \times 10^{24} (g\text{-mole})^{-1}$ . Any deviation from this figure by 2DB would directly affect the data of Table V. There are no figures available for the burnup in the test loops for the 2DB case since the code assumed there was no fissile material present.

The fraction of total power produced in each region is compared in Table VI. These fractions are the same for the REBUS-2 runs with and without A matrix averaging and show excellent agreement with the 2DB values. The trend of the data of Table VI indicates a slightly (several hundreths of a percent) greater flux in the inner core and correspondingly less in the outer rings. Note that for many regions the figures differ by only one digit in the fifth decimal place due to rounding errors and hence the percentage differences are actually less than the listed values. These differences are negligible from an engineering point of view. The power shift relative to the BØC for each of these regions are listed in Table VII and show close agreement.

Rather than comparing EØC mass inventories which, as pointed out above, are directly dependent on the values used for the atomic weights and Avogadro's number, the actual atom densities of the active isotopes, in units of atoms/b-cm, have been tabulated. The BØC and computed EØC values for each of the 14 sample regions are given in Tables VIII-XXI. Here the REBUS-2 results are in excellent agreement with the 2DB values. As noted previously the 2DB problem was by choice not set up to contain the DUMP isotope. Such masses normally have a negligible effect on fuel management studies and hence need not be explicitly accounted for in the calculations. Hence one should compare the EØC DUMP atom densities of the REBUS-2 run with the number of atoms/cc which have been dropped from the calculation at EØC in the 2DB run, i.e., the difference between BØC and EØC total atom densities. Comparison of these figures in Tables VIII-

Table V. lists the burnup computed for each of the 14 comparison ranes Though the REBUS-2 Figures some to within several pursuest of the 200 values, the averages show that the Milus-2 values are participally atgr.

Since the comparison figures are in terms of ship/MT the computes values depend on the values for the atmate metality as as well as the value of Avogadro's number. For the MERUS-2 calculations it was assumed the 200 value of 0.60225 a 100 (sension): Any deviation feet this figure by 200 vauld directly affect the date of lable V. There are no figures available for the burne, in the test longs for the 200 case since the code assumed there was no firstle material persons.

The fraction of total numer produced in unch region is compared in lable VI. These fractions are the same for the UGUS-2 muse with add without A matrix averaging and these excellent agreement at the 200 values. The trend of the data of looks VI indicates a lifety (season) hundreins of a percent) greater flux to the index core and correspondingly less to the autor rings, howe that one many regions the fluxues differ by only one digit to the first decimal place due to rounding errors and hence the percentage differences are acquired to the interest values. The power safety are any indicating notice of the view of the power safety and case of the power safety for each of these regions are listed in Table VII and case values are sach of these regions are listed in Table VII and case values are sach of these regions are listed in

Rather than connecting EDC mass inventories which, as mainted but above, are directly dependent on the values used for the alcule weights and Avogadra's number. Elm accust of the active isotopes, in units of account have been tabulated. The BRG and computed EBC values for such of the in series will-uxi. Here the MRBUS-R results are in excellent are given to lables will the ZRS values. As noted previously the ZRS are in excellent apreciant with the ZRS values the DUMP isotope. Such assess reveally have a negligible affect on rust management studies and mence mend not be explicitly accounted for in the calculations. Mence one should compare the LBC MRWR accounted for in the the REBUS-E run with the number of support inc LBC MRWR accounted for in the law calculation at EBC in the ZRB run, i.e. the difference become from and EBC total atom densities. Comparison of these flames in Tables VIII

TABLE V. FTR Burnup Comparison, MWD/MT

Zone No.	W-2DBª	REBUS-2	Δ, % <sup>b</sup>	REBUS-2, averaged A matrix	Δ, % <sup>b</sup>
1 -	18861	19658	4.23	19690	4.40
3	19999	20017	0.09	20051	0.26
30	19359	19788	2.22	19820	2.38
7	18977	18986	0.05	19019	0.22
10	18585	18580	-0.03	18614	0.16
17	16840	17145	1.81	17176	2.00
20	14114	14308	1.37	14335	1.57
35	17576	17559	-0.10	17593	0.10
40	15564	16041	3.06	16074	3.28
42	15269	15460	1.25	15493	1.47
57	11456	11542	0.75	11567	0.97
61	9741	9951	2.16	9974	2.39
64	12719	12811	0.72	12838	0.94
82		26003		26060	
Inner Core Avg.	17055	17392	*1.98	17423	2.16
Outer Core Avg.	13376	13854	3.57	13882	3.78
Test Loops Avg.		22150		22190	

<sup>&</sup>lt;sup>a</sup>See text concerning value of Avogadro's Number.

<sup>&</sup>lt;sup>b</sup>Relative to 2DB.

dated of ordingtons to suiter or investment year esta

TABLE VI. FTR Power Comparison by Region, Power Fractions

	Zone No.	2DB	REBUS-2ª	Δ, %
вос	1	0.01648	0.01649	0.06
	3	0.01752	0.01753	0.06
	30	0.01694	0.01695	0.06
	7	0.01659	0.01660	0.06
	10	0.01623	0.01624	0.06
	17	0.01467	0.01468	0.07
	20	0.01224	0.01225	0.08
	35	0.01535	0.01537	0.13
	40	0.01355	0.01355	0.0
	42	0.01328	0.01328	0.0
	57	0.00992	0.00991	-0.10
	61	0.00840	0.00837	-0.36
	64	0.01102	0.01100	-0.18
	82	0.000734	0.000736	+0.2
EØC	1	0.01628	0.01628	0.00
	3	0.01726	0.01727	0.0
	30	0.01671	0.01672	0.0
	7	0.01641	0.01641	0.0
	10	0.01609	0.01610	0.0
	17	0.01461	0.01461	0.0
	20	0.01230	0.01231	0.0
	35	0.01528	0.01529	0.0
	40	0.01356	0.01356	0.0
	42	0.01332	0.01333	0.0
	57	0.01004	0.01003	-0.1
	61	0.00857	0.00854	-0.3
	64	0.01114	0.01112	-0.1
	82	0,000716	0.000720	+.56

 $<sup>^{</sup>a}\textsc{B}{\mbox{oth}}$  with and without A matrix averaging.  $^{b}\mbox{Relative to 2DB.}$ 

moth with and without A matrix averaging. Relative to 200.

TABLE VII. FTR Power Comparison by Region, Power Shift, % Relative to BØC

		10 - question (
Zone No.	2DB	REBUS-2ª
1	-1.21	-1.27
3	-1.48	-1.48
30	-1.36	-1.36
7	-1.08	-1.14
10	-0.86	-0.86
17	-0.41	-0.48
20	0.49	0.49
35	-0.46	-0.52
40	0.07	0.07
42	0.30	0.38
57	1.21	1.21
61	2.02	2.03
64	1.09	1.09
82	-2.45	-2.17

<sup>&</sup>lt;sup>a</sup>Both with and without A matrix averaging.

Sorth with and of thank A make's averaging

TABLE VIII. FTR Fuel Inventory Comparison, Region 1 Atom Densities<sup>a</sup>

Isotope	вøс	2DB, EOC	REBUS-2, EØC	$^{ m \Delta}{}^{ m b}$
235U	0.00003140	0.00002773	0.00002773	0.0
238U	0.00548600	0.00539502	0.00539500	-0.00000002
<sup>239</sup> Pu	0.00126900	0.00120215	0.00120213	-0.00000002
<sup>240</sup> Pu	0.00023590	0.00025482	0.00025482	0.0
241Pu	0.00002783	0.00002856	0.00002856	0.0
<sup>242</sup> Pu	0.00000378	0.00000422	0.00000422	0.0
FISHP	0.00028830	0.00042137	0.00042141	0.00000004
DUMP			0.00000834	0.00000834
Total Atoms	0.00734221	0.00733387	0.00734221	0.00000834
Difference from	BØC	-0.00000834 <sup>c</sup>	0.0	
	REBUS-2,	averaged A mas	trix	
235 <sub>U</sub>	REBUS-2,	averaged A ma	trix 0.00002772	-0.00000001
235 <sub>U</sub> 238 <sub>U</sub>	REBUS-2,	averaged A ma		
	REBUS-2,	averaged A ma	0.00002772	-0.00000020
238U	REBUS-2,	averaged A ma	0.00002772 0.00539482	-0.00000020 -0.00000014
238 <sub>U</sub> 239 <sub>Pu</sub>	REBUS-2,	averaged A ma	0.00002772 0.00539482 0.00120201	-0.00000020 -0.00000014
238U 239Pu 240Pu	REBUS-2,	averaged A ma	0.00002772 0.00539482 0.00120201 0.00025486	-0.00000001 -0.00000020 -0.00000014 0.00000004 0.0
238U 239Pu 240Pu 241Pu	REBUS-2,	averaged A ma	0.00002772 0.00539482 0.00120201 0.00025486 0.00002856	-0.00000020 -0.00000014 0.00000004 0.0
238U 239Pu 240Pu 241Pu 242Pu	REBUS-2,	averaged A ma	0.00002772 0.00539482 0.00120201 0.00025486 0.00002856 0.00000422	-0.00000020 -0.00000014 0.00000004
238 <sub>U</sub> 239Pu 240Pu 241Pu 242Pu FISHP	REBUS-2,	averaged A ma	0.00002772 0.00539482 0.00120201 0.00025486 0.00002856 0.00000422 0.00042166	-0.00000020 -0.00000014 0.00000004 0.0 0.0

aIn atom/b-cm.

bREBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculation whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

MARIE VIII, FIR Fuel Inventory Comparison, Region 1 Atom Densities"

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The arp broblem was deliberately jet up in a minner which permitted the products of continue tall and the stall isotopes toget in it to be drapped from the tall culetion whereas in the secule 2 problem they were collected into the put "isotope" include the the put of the secule in the secule in the put in th

TABLE IX. FTR Fuel Inventory Comparison, Region 3 Atom Densities<sup>a</sup>

Isotope	вос	2DB, EØC	REBUS-2, EØC	Δb
235U	0.00004000	0.00003549	0.00003549	0.0
238 <sub>U</sub>	0.00566860	0.00557792	0.00557789	-0.00000003
<sup>239</sup> Pu	0.00142020	0.00134179	0.00134176	-0.00000003
<sup>240</sup> Pu	0.00019200	0.00021499	0.00021500	0.00000001
241Pu	0.00002740	0.00002742	0.00002742	0.0
<sup>242</sup> Pu	0.00000290	0.00000334	0.00000334	0.0
FISHP	0.0	0.00014761	0.00014767	0.00000006
DUMP			0.00000255	0.00000255
Total Atoms	0.00735110	0.00734856	0.00735112	0.00000256
Difference from BØC		-0.00000254°	0.00000002	
235	KEBUS-2	, averaged A mat	0.00003548	-0.00000001
238			0.00003548	-0.00000001 -0.00000021
239pu			0.00337771	-0.00000021
240Pu			0.00021504	-0.00000000
241pu			0.00002742	0.0
242Pu			0.00000334	0.0
FISHP			0.00014795	0.00000034
DUMP			0.00000255	0.00000255
Tatal Atama			0.00735110	0.00000254
Total Atoms				

<sup>&</sup>lt;sup>a</sup>In atom/b-cm.

bREBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculation whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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The 20s amples was delicerately set up in a miles !) to be dropped from the calcaptures in 199, bees, and Fight soctopes (see fig. 1) to be dropped from the calcalaston whereas in the MRMLS dropped they were collected into the index standard and the callest the conserved with the Acceptance of t

TABLE X. FTR Fuel Inventory Comparison, Region 30 Atom Densities<sup>a</sup>

Isotope	вØС	2DB, EØC	REBUS-2, EØC	Δ <sup>b</sup>
2 35 <sub>U</sub>	0.00003546	0.00003142	0.00003142	0.0
2 3 8 U	0.00557700	0.00548681	0.00548677	-0.00000004
<sup>239</sup> Pu	0.00134100	0.00126883	0.00126880	-0.00000003
<sup>240</sup> Pu	0.00021470	0.00023502	0.00023503	0.0000001
<sup>241</sup> Pu	0.00002738	0.00002774	0.00002774	0.0
<sup>242</sup> Pu	0.00000334	0.00000377	0.00000377	0.0
FISHP	0.00014990	0.00028980	0.00028985	0.0000005
DUMP			0.00000540	0.00000540
Total Atoms	0.00734878	0.00134339	0.00734878	0.00000539
Difference from By	øc –	-0.00000539 <sup>c</sup>	0.0	
	REBUS-2	, averaged A ma	trix	
235 <sub>U</sub>			0.00003142	0.0
238 <sub>U</sub>			0.00548660	-0.00000021
<sup>239</sup> Pu			0.00126867	-0.00000016
240Pu			0.00023506	0.0000004
241Pu			0.00002774	0.0
242Pu			0.00000377	0.0
FISHP			0.00029011	0.00000031
DUMP			0.00000541	0.00000541
Total Atoms			0.00734878	0.00000539
Difference from B	øc .		0.0	

aIn atom/b-cm.

BREBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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TABLE XI. FTR Fuel Inventory Comparison, Region 7 Atom Densities<sup>a</sup>

Isotope	вес	2DB, EØC	REBUS-2, EØC	$\Delta^{\mathbf{b}}$
<sup>235</sup> U	0.00004000	0.00003571	0.00003571	0.0
238 <sub>U</sub>	0.00566860	0.00558291	0.00558286	-0.00000005
<sup>239</sup> Pu	0.00142020	0.00134543	0.00134539	-0.00000004
240Pu	0.00019200	0.00021390	0.00021391	0.00000001
<sup>241</sup> Pu	0.00002740	0.00002744	0.00002744	0.0
<sup>242</sup> Pu	0.00000290	0.00000332	0.00000332	0.0
FISHP	0.0	0.00014006	0.00014013	0.00000007
DUMP			0.00000235	0.00000235
Total Atoms	0.00735110	0.00734877	0.00735111	0.00000234
Difference from B&C		-0.00000233°	0.00000001	
235Մ	KEDUS-2	, averaged A ma	0.00003570	-0.00000001
238			0.00558269	-0.00000022
239Pu			0.00134525	-0.00000018
240Pu			0.00021395	0.0000005
241Pu			0.00002744	0.0
<sup>242</sup> Pu			0.00000332	0.0
FISHP			0.00014040	0.00000034
DUMP.			0.00000235	0.00000235
			0	0.0000000
Total Atoms			0.00735110	0.00000233

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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The for problem was deliberatelyingt up in a mander which parentized the products of copings in 27 M, 252PM, and RISME Independential lip to be droped from the Calarsons in the the RISML-2 problem they were collected toto the DUMP "Trotope". Manual this teamure west the RISML-2, EOC DUMP of departs.

TABLE XII. FTR Fuel Inventory Comparison, Region 10 Atom Densities<sup>a</sup>

Isotope	ВОС	2DB, EOC	REBUS-2, EOC	Δ <sup>b</sup>
235U	0.00004000	0.00003582	0.00003582	0.0
238U	0.00566860	0.00558500	0.00558496	-0.0000004
<sup>239</sup> Pu	0.00142020	0.00134721	0.00134718	-0.00000003
240Pu	0.00019200	0.00021302	0.00021303	0.00000001
<sup>241</sup> Pu	0.00002740	0.00002739	0.00002739	0.0
242Pu	0.00000290	0.00000330	0.00000330	0.0
FISHP	0.0	0.00013712	0.00013718	0.00000006
DUMP			0.00000224	0.00000224
Total Atoms	0.00735110	0.00734886	0.00735110	0.00000224
Difference from BOC		-0.00000224 <sup>c</sup>	0.0	
	REBUS-2,	averaged A mat	rix	
235 <b>U</b>			0.00003582	0.0
238U			0.00558480	-0.00000020
<sup>239</sup> Pu			0.00134704	-0.00000017
<sup>240</sup> Pu			0.00021307	0.00000005
241Pu			0.00002739	0.0
<sup>242</sup> Pu			0.00000330	0.0
FISHP			0.00013744	0.00000032
DUMP			0.00000224	0.00000224
Total Atoms Difference from BØC			0.00735110 0.0	0.00000224

aIn atom/b-cm.

b REBUS-2 relative to 2DB

CThe 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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The 200 grables was deliberated to the second of the Fig. I) to be dropped from the calcaptures in the figure and DisHP isotopes (see Fig. I) to be dropped from the calculstrops whereas in the figure a problem they were collected into the DUMP "Isotope" Heace this number wist be connered with the DESUS-2, ISC DUMP atom density

TABLE XIII. FTR Fuel Inventory Comparison, Region 17 Atom Densitiesa

Isotope	врес	2DB, EØC	REBUS-2, EØC	Δb
235 <b>U</b>	0.00003612	0.00003260	0.00003260	0.0
238 <sub>U</sub>	0.00559100	0.00551406	0.00551401	-0.00000005
<sup>239</sup> Pu	0.00135100	0.00128761	0.00128756	-0.00000005
<sup>240</sup> Pu	0.00021080	0.00022790	0.00022792	0.0000002
<sup>241</sup> Pu	0.00002730	0.00002748	0.00002748	0.0
<sup>242</sup> Pu	0.00000327	0.00000362	0.00000362	0.0
FISHP	0.00012970	0.00025186	0.00025195	0.00000009
DUMP			0.00000404	0.00000404
Total Atoms	0.00734919	0.00734513	0.00734918	0.00000405
Difference from BØC		-0.00000406	-0.0000001°	
	REBUS-2	, averaged A ma	atrix	
235 <sub>U</sub>			0.00003260	0.0
238 <b>U</b>			0.00551386	-0.00000020
<sup>239</sup> Pu			0.00128744	-0.00000017
240Pu			0.00022795	0.0000005
241Pu			0.00002748	0.0
242Pu			0.00000362	0.0
FISHP			0.00025218	0.00000032
DUMP			0.00000405	0.00000405
Total Atoms			0.00734918	0.00000405
Difference from BØC			-0.00000001	

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

TABLE SIST. ITS fuel Inventory Conserting Lagion Yr Ayan Densities

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TABLE XIV. FTR Fuel Inventory Comparison, Region 20 Atom Densities<sup>a</sup>

Isotope	ВФС	2DB, EØC	REBUS-2, EØC	$\Delta^{\mathbf{b}}$
235 <b>U</b>	0.00003669	0.00003360	0.00003360	0.0
238 <sub>U</sub>	0.00560300	0.00553715	0.00553709	-0.00000006
<sup>239</sup> Pu	0.00136400	0.00131047	0.00131041	-0.00000006
240Pu	0.00020920	0.00022542	0.00022544	0.00000002
241Pu	0.00002740	0.00002763	0.00002763	0.0
<sup>242</sup> Pu	0.00000322	0.00000354	0.00000354	0.0
FISHP	0.00010630	0.00020890	0.00020899	0.00000009
DUMP			0.00000310	0.00000310
Total Atoms	0.00734981	0.00734671	0.00734980	0.00000309
Difference from BOO		0.00000310 <sup>c</sup>	-0.00000001	
	REBUS-2	averaged A mat	rix	
235 <b>U</b>			0.00003359	-0.0000001
238 <sub>U</sub>			0.00553696	-0.00000019
<sup>239</sup> Pu			0.00131031	-0.00000016
240Pu			0.00022547	0.00000005
241Pu			0.00002763	0.0
242Pu			0.00000355	0.00000001
FISHP			0.00020918	0.00000028
DUMP			0.00000311	0.00000311
Total Atoms			0.00734980	0.00000309
Difference from BØ			-0.00000001	

aIn atom/b-cm.

REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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TABLE XV. FTR Fuel Inventory Comparison, Region 35 Atom Densities a

Isotope	ВОС	2DB, EOC	REBUS-2, EOC	ΔЪ
235 <b>U</b>	0.00003750	0.00003448	0.00003448	0.0
238U	0.00531930	0.00525857	0.00525852	-0.00000005
<sup>239</sup> Pu	0.00173660	0.00165058	0.00165051	-0.00000007
<sup>240</sup> Pu	0.00023480	0.00025270	0.00025272	0.00000002
<sup>241</sup> Pu	0.00003350	0.00003330	0.00003331	0.0000001
<sup>242</sup> Pu	0.00000350	0.00000386	0.00000386	0.0
FISHP	0.0	0.00013014	0.00013025	0.00000011
DUMP			0.00000157	0.00000157
Total Atoms	0.00736520	0.00736363	0.00736522	0.00000159
Difference from BØC		0.00000157°	0.00000002	
	REBUS-2	averaged A mate	rix	
235 <sub>U</sub>			0.00003447	-0.00000001
238 <sub>U</sub>			0.00525840	-0.00000017
<sup>239</sup> Pu			0.00165034	-0.00000024
240Pu			0.00025275	0.0000005
<sup>241</sup> Pu			0.00003331	0.00000001
<sup>242</sup> Pu			0.00000386	0.0
FISHP			0.00013050	0.00000036
DUMP			0.00000157	0.00000157
Total Atoms Difference from BØC			0.00736520	0.00000157
	235U 238U 239Pu 240Pu 241Pu 242Pu FISHP DUMP  Total Atoms Difference from BØC  235U 238U 239Pu 240Pu 241Pu 242Pu FISHP DUMP  Total Atoms	235U 0.00003750 238U 0.00531930 239Pu 0.00173660 240Pu 0.00023480 241Pu 0.0000350 FISHP 0.0 DUMP  Total Atoms 0.00736520 Difference from BØC  REBUS-2 235U 238U 239Pu 240Pu 241Pu 242Pu FISHP DUMP  Total Atoms	235U 0.00003750 0.00003448 238U 0.00531930 0.00525857 239Pu 0.00173660 0.00165058 240Pu 0.00023480 0.00025270 241Pu 0.00003350 0.00003330 242Pu 0.00000350 0.00000386 FISHP 0.0 0.00013014 DUMP  Total Atoms 0.00736520 0.00736363 Difference from BØC REBUS-2 averaged A mate	235U   0.00003750   0.00003448   0.00003448   238U   0.00531930   0.00525857   0.00525852   239Pu   0.00173660   0.00165058   0.00165051   240Pu   0.00023480   0.00025270   0.00025272   241Pu   0.00003350   0.00003330   0.00003331   242Pu   0.00000350   0.0000386   0.00000386   FISHP   0.0   0.00013014   0.00013025   0.0000157   0.00000157   Total Atoms   0.00736520   0.00736363   0.00736522   0.00000002   0.00000002   0.0000000000

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

The 200 problem was deliberately set up to a manner which permitted the preducts of contained in Early Release (see 210. 1) to be dropped from the call cultures in the help's problem they have collected into the DEFE trackers in the DEFE trackers they have collected into the DEFE trackers.

TABLE XVI. FTR Fuel Inventory Comparison, Region 40 Atom Densities<sup>a</sup>

Isotope	вøс	2DB, EØC	REBUS-2, EOC	$\Delta^{\mathbf{b}}$
235 <sub>U</sub>	0.00003188	0.00002938	0.00002938	0.0
238 <b>U</b>	0.00520300	0.00514532	0.00514533	0.0000001
<sup>239</sup> Pu	0.00157900	0.00150715	0.00150716	0.0000001
240 <b>Pu</b>	0.00027000	0.00028499	0.00028498	-0.00000001
<sup>241</sup> Pu	0.00003358	0.00003384	0.00003384	0.0
<sup>242</sup> Pu	0.00000421	0.00000455	0.00000455	0.0
FISHP	0.00023850	0.00035043	0.00035039	-0 .00000004
DUMP			0.00000453	0.00000453
Total Atoms	0.00736017	0.00735566	0.00736016	0.00000450
Difference from BØ0		0.00000451 <sup>c</sup>	-0.0000001	
	REBUS-2	, averaged A ma	trix	
<sup>235</sup> U			0.00002937	-0 .00000001
238 <sub>U</sub>			0.00514522	-0.00000010
<sup>239</sup> Pu			0.00150703	-0.00000012
240Pu			0.00028501	0.0000002
241Pu			0.00003384	0.0
242Pu			0.00000455	0.0
FISHP			0.00035061	0.00000018
DUMP			0.00000454	0.00000454
Total Atoms			0.00736017	0.00000451
Difference from BO			0.0	

aIn atom/b-cm.

REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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TABLE XVII. FTR Fuel Inventory Comparison, Region 42 Atom Densities<sup>a</sup>

Isotope	ВØС	2DB, E0°C	REBUS-2, EØC	$\Delta^{\mathbf{b}}$
235 <sub>U</sub>	0.00003478	0.00003224	0.00003224	0.0
238 <b>U</b>	0.00526500	0.00521085	0.00521087	0.00000002
<sup>239</sup> Pu	0.00165900	0.00158607	0.00158609	0.00000002
<sup>240</sup> Pu	0.00025110	0.00026614	0.00026613	-0.00000001
<sup>241</sup> Pu	0.00003336	0.00003340	0.00003340	0.0
242Pu	0.00000382	0.00000414	0.00000414	0.0
FISHP	0.00011660	0.00022811	0.00022809	-0.00000002
DUMP	1 ( ) <del></del> -   - 1 ( )		0.00000270	0.00000270
Total Atoms	0.00736366	0.00736095	0.00736366	0.00000271
Difference from BÓC		0.00000271 <sup>c</sup>	0.0	
	REBUS-2,	averaged A mat	rix	
235 <sub>U</sub>			0.00003224	0.0
238U			0.00521076	-0.00000009
<sup>239</sup> Pu			0.00158595	-0.00000012
240Pu			0.00026616	0.00000002
<sup>241</sup> Pu			0.00003340	0.0
242Pu			0.00000414	0.0
FISHP			0.00022830	0.00000019
DUMP			0.00000271	0.00000271
Total Atoms			0.00736366	0.00000271
			0.0	

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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HERNS-2 relative to 200

The 202 problem was deliberately set up in a manner writin permitted the products of compared in the 22 dropped from the set up the compared from they were collected from the filler interest in the greek to the compared with the che debus as EDC CUPP atom density.

TABLE XVIII. FTR Fuel Inventory Comparison, Region 57 Atom Densities a

Isotope	вøс	2DB, EØC	REBUS-2, EØ℃	Δ
235U	0.00003531	0.00003324	0.00003324	0.0
238 <b>U</b>	0.00527800	0.00523650	0.00523655	0.00000005
239Pu	0.00167600	0.00161819	0.00161825	0.00000006
<sup>240</sup> Pu	0.00025010	0.00026450	0.00026447	-0.00000003
<sup>241</sup> Pu	0.00003427	0.00003519	0.00003518	-0.00000001
242Pu	0.00000378	0.00000407	0.00000407	0.0
FISHP	0.00008698	0.00017076	0.00017069	-0.00000007
DUMP			0.00000199	0.00000199
Total Atoms	0.00736444	0.00736245	0.00736444	0.00000199
Difference from BØC		<b>-0</b> .00000199 <sup>c</sup>	0.0	
	REBUS-2	, averaged A mat	trix	
235 <b>U</b>			0.00003324	0.0
238U			0.00523647	0.00000003
<sup>239</sup> Pu			0.00161814	0.00000005
<sup>240</sup> Pu			0.00026450	0.0
241Pu			0.00003518	0.0000001
242Pu			0.00000407	0.0
FISHP			0.00017085	0.00000009
DUMP			0.00000199	0.00000199
Total Atoms			0.00736444	0.00000199
Difference from BØC	he delan		0.0	

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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TABLE XIX. FTR Fuel Inventory Comparison, Region 61 Atom Densitiesa

Isotope	вос	2DB, EØC	REBUS-2, EØC	$\triangle$ b	
235 <b>U</b>	0.00003199	0.00003028	0.00003029	0.00000001	
238U	0.00521100	0.00517406	0.00517422	0.00000016	
<sup>239</sup> Pu	0.00158500	0.00153737	0.00153757	0.00000020	
<sup>240</sup> Pu	0.00027410	0.00028619	0.00028613	-0.00000006	
<sup>241</sup> Pu	0.00003617	0.00003729	0.00003727	-0.00000002	
242Pu	0.00000426	0.00000454	0.00000454	0.0	
FISHP	0.00021840	0.00028804	0.00028780	-0.00000024	
DUMP		2.00010001	0.00000311	0.00000311	
Total Atoms	0.00736092	0.00735777	0.00736093	0.00000316	
Difference from BOC		-0.00000315 <sup>c</sup>	0.00000001		
	REBUS-2	, averaged A mat	trix		
2350			0.00003029	0.00000001	
238 <sub>U</sub>			0.00517415	0.00000009	
<sup>239</sup> Pu			0.00153748	0.00000011	
240Pu			0.00028615	0.00000004	
241Pu			0.00003727	0.00000002	
242Pu			0.00000454	0.0	
FISHP			0.00028793	0.00000011	
DUMP			0.00000312	0.00000312	
Total Atoms			0.00736093	0.00000314	
Difference from B∅C			0.00000001		

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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TABLE XX. FTR Fuel Inventory Comparison, Region 64 Atom Densities<sup>a</sup>

Isotope	ВОС	2DB, EØC	REBUS-2, EØC	$\Delta^{\mathbf{b}}$
235U	0.00003521	0.00003303	0.00003303	0.0
238 <sub>U</sub>	0.00527400	0.00522859	0.00522873	0.00000014
<sup>239</sup> Pu	0.00167200	0.00161032	0.00161047	0.00000015
240Pu	0.00024920	0.00026282	0.00026277	-0.00000005
<sup>241</sup> Pu	0.00003357	0.00003379	0.00003378	-0.00000001
<sup>242</sup> Pu	0.00000378	0.00000406	0.00000406	0.0
FISHP	0.00009592	0.00018901	0.00018880	-0.00000021
DUMP			0.00000204	0.00000204
Total Atoms	0.00736368	0.00736162	0.00736368	0.00000206
Difference from BO	С	0.00000206 <sup>c</sup>	.0	
235	112000 2	, averaged A ma	0.00003303	0.0
238Մ			0.00003303	0.00000005
239Pu			0.00322004	
ru			0.00161035	
240 pi			0.00161035	0.00000003
240Pu 241Pu			0.00026279	0.00000003
241Pu				0.00000003
<sup>241</sup> Pu <sup>242</sup> Pu			0.00026279 0.00003378	0.00000003 -0.00000003 -0.00000001
241Pu			0.00026279 0.00003378 0.00000406	0.00000003 -0.00000001 -0.00000001 0.0
241p <sub>U</sub> 242p <sub>U</sub> FISHP			0.00026279 0.00003378 0.00000406 0.00018898	0.00000003 -0.00000001

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{24}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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The 200 problem was deliberately set up in a manner which committed the products of castumes in 10 to be drapped from The call castume in the Table 2 problem topy were inlicated into the DAST "Sobope calletions where the the DAST "Sobope 2 problem topy with the DAST "Sobope 2 problem to the DAST" "Sobope 2 problem to the DAST" Sobope 2 problem to the DAST "Sobope 2 problem to the DAST" Sobope 2 problem to the DAST Sobo

TABLE XXI. FTR Fuel Inventory Comparison, Region 82 Atom Densities<sup>a</sup>

Isotope	вос	2DB, EØC	REBUS-2, EOC	Δ <sup>b</sup>
2350	0.00005190	0.00004750	0.00004748	-0.0000002
238 <b>U</b>	0.00013230	0.00013086	0.00013086	0.0
<sup>239</sup> Pu	0.00004580	0.00004348	0.00004348	0.0
<sup>240</sup> Pu	0.00000620	0.00000688	0.00000688	0.0
241Pu	0.0	0.0	0.00000018	0.00000018
<sup>242</sup> Pu	0.0	0.0	0.0	0.0
FISHP	0.0	0.0	0.00000615	0.00000615
DUMP	Two tee times	olicon etpelosito	0.00000118	0.00000118
Total Atoms	0.00023620	0.00022872°	0.00023621	0.00000749
Difference from I	зфс	0.00000748	0.00000001	
	REBUS-2	, averaged A ma	trix	
2350			0.00004747	-0.00000003
238U			0.00013086	0.0
239Pu			0.00004347	-0.00000001
240Pu			0.00000688	0.0
241Pu			0.00000018	0.00000018
242Pu			0.0	0.0
FISHP			0.00000616	0.00000616
DUMP			0.00000118	0.00000118
Total Atoms			0.00023620	0.00000748
Difference from B	3 ØC		0.0	

aIn atom/b-cm.

b REBUS-2 relative to 2DB

<sup>&</sup>lt;sup>C</sup>The 2DB problem was deliberately set up in a manner which permitted the products of captures in  $^{235}$ U,  $^{242}$ Pu, and FISHP isotopes (see Fig. 1) to be dropped from the calculations whereas in the REBUS-2 problem they were collected into the DUMP "isotope". Hence this number must be compared with the REBUS-2, EØC DUMP atom density.

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#### IV. CONCLUSIONS

The calculational procedure selected by user option for the 2DB code is very close though not identical to that of REBUS-2. In the latter the EDC flux was explicitly computed rather than a renormalization of the BDC flux as in the former. This mode of operation for 2DB is based on an engineering design experience and indeed as has been seen the 2DB computed data is in general very close to that of the REBUS-2 code. The burnup swing is 0.08% less and 2% more poison was required by 2DB to achieve the same BØC  $k_{eff}$ . For the same poison eigenvalue, the REBUS-2 code gives a BØC  $k_{\rm off}$  which is 0.04% smaller than the 2DB value. Burnup values in MWD/MT shows the greatest deviation from the REBUS-2 results — differences on the order of several percent with the REBUS-2 overall core averages high by about 3%. These differences may be in part attributable to differences in the value of Avogadro's number assumed in the two codes. Power fractions are in much better agreement showing deviations ranging from tenths to hundredths of a percent. The pattern of deviations indicates a slightly lesser power output in the inner core regions and slightly greater in the outer regions compared with REBUS-2 although the difference is negligibly small from an engineering standpoint. Atom densities for the 14 sample regions show slight differences in power fractions. The consistently high burnup values and the slightly greater value of  $\Delta k_{off}$  indicate the REBUS-2 problem is operating at a power level which is effectively slightly higher than that of the 2DB run. Likewise, the poison eigenvalue of Table IV as well as the values of the derivative  $\Delta k_{\text{eff}}/\Delta x$  mentioned previously indicate the presence of an absorber in the REBUS-2 run which is not present in the 2DB calculations. Detailed examination of the data has shown no discrepancies to which these minor variations can be attributed.

A second comparison run of REBUS-2 using its normal rigorous operating mode in which an average burn matrix is utilized for the burnup across a subinterval also showed very small atom density differences with respect to 2DB. Other quantitities were not appreciably affected, the largest change being a slightly greater burnup swing.

mode in which an average burn matrix is utilized for the burnup across a sublinterval sise shawed very small atom density differences with respect to 208. Other quantitatives were not exprecisely affected, the largest change being a slightly greater burnup swing.

The overall conclusion is that the data predictions of REBUS-2 and 2DB are in excellent agreement and verify the suitability of the REBUS-2 code for FTR calculations. Differences noted are small and would not affect any design decision or operation predictions.

## V. ACKNOWLEDGMENT

The author would like to thank Colin Durston for many helpful discussions concerning these comparison calculations.

The overall conclusion is that the data predictions of REND-2 and 202 are to eachieft agreement and verify the suitability of the REND-2 code for FTE conclusions. Differences noted are small and mould not wifeet any design deciries on operation predictions.

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